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DESCRIPTION

TAPE-SHAPED MOLDING AND BELT FOR BALL CHAIN

[TECHNICAL FIELD]

The present invention relates to a tape-shaped product and a belt for ball chain used in a guide device for linear motion on a track utilizing the rolling of a plurality of rolling members, such as balls or rollers (hereinafter representatively referred to as "ball(s)").

[BACKGROUND ART]

Hitherto, various tape-shaped products of thermal resins are known, but almost no proposals have been made regarding a tape-shaped product suitable for forming a belt including a planar tape portion provide with a multiplicity of holes for retaining another object thereat. As an example of such a belt including a planar tape portion provided with a multiplicity of holes for holding another object thereat, there is an endless belt retaining balls rollably thereon for a guide device for linear motion on a track. As disclosed in Japanese Laid-Open Patent Application (JP-A) 5-52217, such a belt includes ball-retaining portions intervening a plurality of balls arranged with prescribed intervals

ATTACHMENT C

in a row, and a flexible connecting member for connection between the respective ball-retaining portions.

For the production of a belt for ball chain (hereinafter sometimes referred as a ball chain belt), there are known a method of forming prescribed ball-retaining holes in an extruded tape, and a method of direct injection molding without via such a tape product. An example of the former method is disclosed in JP-A 2001-74048 wherein an elongated flat tape product (i.e., a belt member) is preliminarily formed by extrusion and is cut in a prescribed length to form a row of holes for loosely retaining balls, and spacer portions are formed between adjacent retaining holes for retaining balls while using the balls as inserts. In the case of forming a tape product (a belt member) by extrusion of a synthetic resin and then forming ball-retaining holes for retaining balls rollably, it is difficult to obtain a strength sufficient for using the product as an endless belt subject to sliding movement. Further, the adhesion between the spacer portions formed by injection molding and the belt member is insufficient to cause the dropping-off of the spacer portions. For this reason, for the purpose of ensuring a tensile strength and a flexural strength of the belt member, JP-A 2001-74048 also discloses a

method of using two extruders for extruding a resin functioning as a reinforcing material and a resin coating the reinforcing material to form a tape portion through a common die, and an extrusion forming method of embedding reinforcing members, such as glass fiber, carbon fiber or ceramic fiber along parallel longitudinal edges of a flat band-shaped belt. However, the above-mentioned method of co-extruding two types of resins for forming a reinforcing member cannot provide a sufficient strength, and if a large ratio of stretching is applied thereto for providing an increased strength, the thermal shrinkability becomes larger, so that the product is not suitable for such use as an endless belt for retaining balls rollably in a linear motion guide device. On the other hand, the fiber, such as glass fiber, carbon fiber or ceramic fiber, of a material different from the belt-forming material cannot be sufficiently strongly bonded with the belt-forming material, so that these materials are liable to form a gap therebetween due to various loads during use, and the strength is rapidly lowered if the gap occurs, thus involving a problem regarding the durability.

Further, in another method of producing a ball chain belt as disclosed in, e.g., JP-A 11-247856, ball frames having a diameter larger than that of balls

used for the ball chain are aligned in projection at prescribed intervals in a metal mold for injection molding of synthetic resin, and a synthetic resin is injected into the metal mold to form a connecting belt with the ball frames aligned therein, followed by taking-out of the connecting belt from the metal mold and pushing-in of balls into the ball frames of the molded product so as to rollably retain the balls therein. According to this method, it is very difficult to develop a sufficient size accuracy, and even if a sufficient accuracy can be attained, the metal mold production cost becomes very expensive. Further, the taking-out of the product from the mold is difficult, and the proportion of defectives is liable to be higher due to the occurrence of fins around the holes.

In another method as disclosed in, e.g., JP-A 5-196037, a plurality of ball pieces disposed between balls and a connecting band connecting the ball pieces and provided with ball holes for receiving the balls are integrally formed by injection molding. In the injection method, resins injected out of respective gates are joined together at an intermediate point between the gates to form a weld, of which the strength is liable to be lowered.

As described above, there has not been provided a tape-shaped product suitable for forming a belt

including a planar tape portion provided with a multiplicity of holes for retaining another object thereat. Further, the production of the belt members according to the above-mentioned methods is complicated, and it is difficult to attain a desired strength by the products.

[DISCLOSURE OF INVENTION]

The inventors have studied for the purpose of providing a tape-shaped product suitable for forming a belt including a planar tape portion provided with a multiplicity of holes for retaining another object thereat and having a large tensile strength, and a shaped product having a large tensile strength as a belt chain belt having a large tensile strength for rollably retaining balls aligned in a row, to arrive at the present invention.

An object of the present invention is to provide a tape-shaped product suitable for forming a belt including a planar tape portion provided with a multiplicity of holes or a belt for retaining another object at such holes, or a belt for ball chain (i.e., a ball chain belt) having an excellent ball-retaining power and a durability.

The present invention relates to a tape-shaped product of thermoplastic resin which contains a preliminarily stretched fibrous member of

thermoplastic resin (hereinafter referred to as "stretched fibrous member") along longitudinally parallel edges or in proximity thereto. It is preferred that the stretched fibrous member comprises a resin having a good adhesion and moldable together with the resin forming the tape other than the fibrous member, and that the tape-shaped product has a longitudinal tensile strength of at least 250MPa and a thermal shrinkability of at most 1%, more preferably a longitudinal tensile strength of at least 300MPa and a thermal shrinkability of at most 0.5%

The present invention further relates to a tape-shaped product of synthetic resin formed by injection molding together with a stretched fibrous member of a thermoplastic resin having a good adhesion with the stretched fibrous member, and provided with the stretched fibrous member contained therein at positions along longitudinally parallel edges or in proximity thereto, ball-insetting holes disposed at equal intervals in a straight line, and ball-retaining members (which need not hold the balls but are sufficient if they prevent a direct contact of mutually adjacent balls). In the ball chain belt of the present invention, the stretched fibrous member may comprise a synthetic resin having a good adhesion with and moldability together with the resin

forming the belt other than the stretched fibrous member, and the belt may exhibit a tensile strength of at least 100MPa, a ball-retaining power of at least 30MPa when balls are inset in the ball-insetting holes, and a thermal shrinkability of at most 1%. It is preferred that the tensile strength is at least 150MPa, the ball-retaining power is at least 45MPa when the balls are inset in the ball-insetting holes, and the thermal shrinkability is at most 0.5%. In this instance, it is sufficient that the stretched fibrous member is disposed at positions outside the insetting holes.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig.1 is a perspective view showing a tape-shaped product of the invention.

Fig.2 shows a ball chain belt of the invention, including a planar view at (a), a longitudinal sectional view at (b) and a lateral side view at (c).

Fig.3 shows states of stretched fibrous members being set in a mold for forming a tape-shaped product of the invention, including a longitudinal sectional view at (a) and a lateral sectional view at (b).

Fig.4 is a perspective view of a comparative tape-shaped product not containing stretched fibrous members.

Fig.5 shows a comparative composite tape-shaped product containing co-extruded cores.

Fig.6 is a view showing a state of forming ball-insetting holes in a tape-shaped product of the invention.

Fig.7 is a view showing a state wherein stretched fibrous members and balls are set in a mold for forming a ball chain belt of the invention.

Fig.8 shows a comparative ball chain belt free of stretched fibrous members, including a planar view at (a), a longitudinal side view at (b) and a lateral side view at (c).

Fig.9 shows a comparative ball chain belt free of stretched fibrous members, including a planar view at (a), a longitudinal side view at (b) and a lateral side view at (c).

Fig.10 is a view showing a state of forming ball-insetting holes in a comparative tape-shaped product free of stretched fibrous members.

Fig.11 is a view showing a state wherein rollers are set in a mold for forming a roller-type ball chain belt of the invention.

Fig.12 shows views of a roller-type ball chain belt of the invention, including a planar view at (a), a longitudinal side view at (b) and a lateral side view at (c).

Fig.13 is a perspective view of a linear motion

guide device in which a ball chain according to the invention has been incorporated.

Fig.14 is a perspective view of a linear motion guide device in which a roller-type ball chain according to the invention has been incorporated.

Fig.15 is a sectional view of a ball screw in which a ball chain according to the invention has been incorporated.

Respective symbols correspond to respective component members as follows.

1: stretched fibrous member, 2:tape member, 3:ball-retaining hole, 4:ball-retaining member, 5:ball for molding, 6:core, 7:ball-insetting state, 8:mold, 9:roller-retaining hole, 10:roller-retaining member, 11:linear motion guide device, 12: tracking rail, 13:movable block body, 14:ball chain, 15:linear motion guide device, 16:tracking rail, 17:movable block body, 18:roller-type ball chain, 19:ball screw, 20:screw shaft, 21:nut, 22:return pipe, 23:ball chain (ball belt and balls)

[BEST MODE FOR PRACTICING THE INVENTION]

A tape-shaped product according to a first invention is shown in Fig.1, and comprises a stretched fibrous members 1 and injected resin 2. The stretched fibrous members 1 are set in advance in a mold so as to be contained in the resultant

molded product along longitudinally parallel edges or positions proximate thereto of the molded product, and a resin moldable together with and having a good adhesion with the stretched fibrous members is molded by injection to form the tape-shaped member (injection-molded resin member) 2 integral with the stretched fibrous members 1. As a result, it is possible to obtain a resinous tape-shaped product having a longitudinal tensile strength of at least 250MPa and a thermal shrinkability of at most 1%, preferably a longitudinal tensile strength of at least 300MPa and a thermal shrinkability of at most 0.5%. Incidentally, the thermal shrinkabilities are based on values measured after allowing samples to stand for 24 hours under no tension at 40℃ (dry).

A ball chain belt according to a second invention is shown in Fig.2 including a planar view at (a), a longitudinal side view at (b) and a lateral side view at (c), and comprises stretched fibrous members 1 along longitudinally parallel edges or at positions proximate thereto of a tape-shaped product, a tape-shaped member (of injection-molded resin) 2, a multiplicity of ball-insetting holes 3 disposed at equal intervals aligned in a central portion of the tape member 2, and ball-retaining members 4 each disposed between adjacent ball-insetting holes 3. In this instance, it is sufficient that the stretched

fibrous members 1 are disposed at position outside the ball-insetting holes 3. Dashed lines 7 in Fig.2 each represents a state of a ball being inset in position.

A ball chain belt of the present invention as described above may be produced in the following manner. That is, in a tape-shaped product containing stretched fibrous members (Fig.1) produced in the above-described manner, holes 3 having a diameter slightly larger than that of a ball (or roller) retained therein are formed at equal intervals by perforation as shown in Fig.6, balls for molding are inset in the holes 3, and ball-retaining members 4 are formed in projection by injection molding around the holes 3. Alternatively, without via such a tape-shaped product, balls 5 having a diameter slightly larger than that of a ball retained therein and stretched fibrous members 1 are disposed in a mold as shown in Fig.7, and a prescribed resin is injection-molded to integrally form the tape member 2 and the retaining members 4. Thus, a shaped product containing the stretched fibrous members along the longitudinally parallel or at positions proximate thereto and fixing a mid portion of the balls is formed, and then the balls for molding are taken out to provide a ball chain belt. By using the ball chain belt, prescribed balls to be retained

are inset at respective holes to provide a ball chain rollably retaining the balls.

Herein, the preliminarily stretched fibrous member(s) refers to a fibrous member including oriented molecular chains obtained by stretching a yet-unstretched fibrous member formed by fiber spinning. The stretching may be performed by any method capable of providing an enhanced orientation of the fibrous member. For example, it is possible to adopt a method of subjecting such a yet-unstretched fibrous member continuously to a stretching step. Alternatively, such a yet-unstretched fibrous member may be later subjected to a separate stretching step. The stretching may be effected in a single step or multiple steps including two or more steps, and may also include a step of heat-treatment, etc. The stretching medium may be gas, liquid or a hot plate and need not be restricted particularly. Further, it is also possible to adopt a direct spinning-stretching method wherein a resin ejected out of a spinning nozzle is subjected to drafting. The preliminarily stretched fibrous member of thermoplastic resin may comprise stretched fiber having a tensile strength of at least 300MPa, preferably 450 – 1000MPa and may be in the form of a mono-filament or multi-filaments. The stretched fibrous member may comprise composite-structured fiber (e.g., core/sheath

structure), combined yarn fiber, twisted yarn fiber or non-circular section fiber, or any other form as far as it can retain an adhesion with the injected resin to exhibit a sufficient strength. As the preliminarily stretched fibrous member of thermoplastic resin, it is preferred to use a mono-filament (in a sense of including a core-sheath type composite yarn) of a resin of the same kind as the resin for injection molding.

The resins moldable together and having a good adhesion with each other need not be entirely identical but may be those including principal components of identical resins, may be resins of a same type or family, or may include a stretched fibrous member of which the surface is chemically or physically treated to exhibit such an adhesiveness as not to cause a practically easy separation. The resin for injection molding is not particularly restricted as far as it allows injection molding, but may comprise various elastomers (e.g., polyester-type, nylon-type, polyolefin-type, acryl-type, fluorine-containing resin-type), or various synthetic resins (e.g., polyester-type, nylon-type, polyolefin-type, acryl-type, fluorine-containing resin-type), etc.

Specific combinations of the stretched fibrous member and the injection molding resin may include a combination of identical resins, and also

combinations of a PVDF/PMMA core/sheath composite yarn and acryl-type elastomer, polyester-type elastomer, PBT-type elastomer, or like; a PVDF/PMMA mixture fiber and the above-mentioned elastomer; PMMA-impregnated UHMWPE fiber string and PMMA, etc.

In the tape-shaped product formed from the stretched fibrous member and a resin moldable together and having a good adhesion therewith through injection molding, the stretched fibrous member may desirably occupy a ratio of 10-70%, preferably 20-60%, of a sectional area perpendicular to the longitudinal direction. The ratio can vary depending on the size, desired strength, etc., of the tape-shaped product.

In the tape-shaped product of the present invention, the molded resin portion other than the fibrous member has an orientation which is lower than that of the fibrous member and in such a degree as to provide a thermal shrinkability of the tape-shaped product of preferably at most 1%, more preferably at most 0.5%.

The tape-shaped product of the present invention may have a shape of section perpendicular to the longitudinal direction, which shape is not restricted to a quadrangle or rectangle having 4 sides, but may also be a trigon, a polygon, each capable of

including one or more curved sides, or further an ellipse or a shape formed by dividing an ellipse into two halves.

The tape-shaped product of the present invention may have a section as described above exhibiting a ratio of a maximum thickness to a width in a range of 1:50 – 1:1, preferably 1:20 – 1:1, further preferably 1:15 - 1:2. It is particularly preferred that the tape-shaped product has a sectional shape of a rectangle exhibiting a ratio of a maximum thickness to a width of 1:15 – 1:2.

A ball chain obtained by insetting balls in a tape-shaped product of the present invention may preferably be used as a ball-connecting member in a linear motion guide device equipped with a ball-retaining endless circulation path, and in a ball screw device as disclosed in, e.g., JP-A 11-37246.

[Examples]

Hereinbelow, the present invention will be described more specifically based on Examples and Comparative Examples. Incidentally, the measurement conditions for thermal shrinkability, tensile strength and elongation in the following Examples and Comparative Examples are as follows.

(Measurement method and measurement conditions)

(1) Thermal shrinkability

Measured at a temperature of 40℃ (dry) for a time of 24 hours.

(2) Tensile strength and elongation

Measured by subjecting a test piece of 50mm in length to a tensile speed of 50mm/min. by using Tension UCT=100Model (made by Orientec K.K.) in an environment at a temperature of 23℃.

(3) Ball-retaining strength of ball chain belt.

A ball is inset in a third hole from an end of a ball chain belt, which is then subjected to measurement in the same manner as tensile strength.

A ball chain belt is provided with circular holes and therefore has different sectional areas at respective positions, and the breakage occurs at a portion of the smallest sectional area. The ball-retaining strength is calculated based on the smallest sectional area.

Physical properties of products obtained in Examples and Comparative Examples are inclusively shown in Tables 1 and 2.

(Example 1)

A polyester elastomer of MFR=10 was spun at a resin temperature of 240℃ through a 50mm-dia. extruder to form an unstreched filament. The unstretched filament was stretched at 5.8 times in a hot air oven of 150℃ and relaxed by 10% in a hot air oven at 180℃ to obtain a stretched filament of 200

μm. The stretched filament exhibited a tensile strength of 470MPa and an elongation of 86%.

Then, the stretched filament was set in a mold for injection molding as shown in Fig.3 and an identical resin as the stretched filament was injected at 280℃ in the mold to form a tape-shaped product as shown in Fig.1 having a width of 0.65mm and a thickness of 0.24mm. The stretched filament occupied 40% of a sectional area perpendicular to the longitudinal direction. As is understood form the physical properties shown in Table 1, the shaped product exhibited a high tensile strength, a low thermal shrinkability, and thus a good size accuracy.

(Comparative Example 1)

<Comparative Example 1-(1)>

An identical resin as in Example 1 was used in the same manner as in Example 1 except for not setting the stretched filament to form a tape-shaped product as shown in Fig.4 having a width of 0.65mm and a thickness of 0.24mm. The product exhibited a much lower tensile strength of 61MPa than the shaped product of Example 1.

<Comparative Example 1-(2)>

A polyester elastomer of MFR=10 was spun at a resin temperature of 240℃ through a 50mm-dia. extruder to form an unstretched filament. Then, similarly as in Example 1, the unstretched filament

was set in a mold for injection molding as shown in Fig.3, and an identical resin as the unstretched filament was injected into the mold for injection molding, to form a tape-shaped product as shown in Fig.1 having a width of 0.65mm and a thickness of 0.24mm. The product exhibited a much lower tensile strength of 65MPa than the shaped product of Example 1.

From these Comparative Examples, the effectiveness of disposing the stretched filaments in Example 1 is understood.

(Comparative Example 2)

A tape-shaped product not containing stretched fibrous members unlike the shaped product of Example 1 was produced by extrusion.

<2-(1)>

A tape-shaped product as shown in Fig.4 was obtained by using a 50mm-dia. extruder instead of injection molding in Example 1.

<2-(2)>

A tape-shaped product was formed by extrusion in the same manner as in the above 2-(1), followed successively by stretching at 5.8 times in a hot air oven at 150℃ and relaxation by 10% in a in a hot air oven at 180℃ to obtain a tape-shaped product as shown in Fig.4.

<2-(3)>

A tape-shaped product was formed by extrusion in the same manner as in the above 2-(1), followed successively by stretching at 6.25 times in a hot air oven at 180℃ and relaxation by 30% in a hot air oven at 320℃ to obtain a tape-shaped product as shown in Fig.4.

<2-(4)>

A tape-shaped product as shown in Fig.4 was obtained in the same manner as in the above 2-(2) except that the stretching ratio was changed to 6.9 times.

The tape-shaped products of Comparative Examples 2-(1) to 2-(4) not containing stretched filaments but obtained through extrusion exhibited lower tensile strengths. The extruded products when further subjected to stretching exhibited a large tensile strength but were accompanied with an undesirably larger thermal shrinkability of the shaped products at a larger stretching ratio. Further, in any case, the products failed to exhibit a sufficient strength compared with the shaped product of Example 1.

(Example 2)

A core/sheath-type composite yarn (core/sheath ratio=80/20% by volume) with a core of polyester elastomer of MFR=10 and a sheath of polyester elastomer of MFR=17 was spun at a resin temperature

of 240℃ to form an unstretched filament. The unstretched filament was stretched at 5.8 times in a hot air oven of 180℃ to form a stretched filament of 200 μm. The stretched filament exhibited a tensile strength of 437MPa and an elongation of 71%. By using the stretched filament and a polyester elastomer of MFR=10, a tape-shaped product as shown in Fig.1 having a width of 0.65mm and a thickness of 0.24mm was obtained in the same manner as in Example 1. In the tape-shaped product, the stretched filament occupied 40% of a sectional area perpendicular to the longitudinal direction. The shaped product also exhibited excellent physical properties similarly as the shaped product of Example 1.

(Comparative Example 3)

A tape-shaped product (as shown in Fig.5) having cores 6 corresponding to the stretched filament in Example 2 was produced by co-extrusion.

<3-(1)>

Instead of the injection molding in Example 2, a polyester elastomer of MFR=10 and a polyester elastomer of MFR=17 were co-extended so that the polyester elastomer of MFR=10 formed 0.2 mm-dia. cores along both edges of a shaped tape, thus producing a tape-shaped product (width=0.65mm, thickness=0.24mm, core diameter=0.2mm) as shown

in Fig.5 containing cores 6.

<3-(2)>

A core-containing tape-shaped product was formed by co-extrusion in the same manner as in the above 3-(1), and then stretched at 5.8 times in a hot air oven at 150℃ and further relaxed by 10% in a hot air oven at 180℃ to obtain a core-containing tape-shaped product (width=0.65mm, thickness= 0.24mm, core diameter=0.2mm) as shown in Fig.5

<3-(3)>

A core-containing tape-shaped product was formed by co-extrusion in the same manner as in the above 3-(2), and then stretched at 6.25 times in a hot air oven at 180℃ and further relaxed by 10% in a hot air oven at 220℃ to obtain a core-containing tape-shaped product (width=0.65mm, thickness= 0.24mm, core diameter=0.2mm) as shown in Fig.5

<3-(4)>

A core-containing tape-shaped product (width=0.65mm, thickness=0.24mm, core diameter= 0.2mm) as shown in Fig.5 was produced in the same manner as in the 3-(2) above except that the stretch ratio was changed to 6.7 times.

From the above 3-(1) to 3-(4), the stretched core-containing tape-shaped products obtained by forming a tape-shaped product containing core-forming resin along both edges thereof by extrusion and

subsequent stretching failed to exhibit a sufficient strength compared with the tape-shaped product obtained by injection molding together with the stretched filament and, if the stretching ratio was further increased for providing an increased strength, were liable to cause a separation between the cores and the tape.

(Example 3)

A 6/66-copolymer nylon resin having a relative viscosity of 3.5 was spun at a resin temperature of 230 ℃ through a 50mm-dia. extruder to obtain an unstretched filament. The unstretched filament was subjected to a first step-stretching at 3.6 times in a warm water bath at 85 ℃ and then a second step-stretching at 1.5 times in a hot air oven at 185 ℃, followed further by relaxation by 15% in a hot air oven at 165 ℃ to obtain a stretched filament. The stretched filament exhibited a tensile strength of 815 MPa and an elongation of 45 %. Then, similarly as in Example 1, the stretched filament was set in a mold for injection molding as shown in Fig.3, and an identical resin as the stretched filament was injected at 240 ℃ into the mold to form a tape-shaped product as shown in Fig.1. The stretched filament occupied 40 % of a sectional area perpendicular to the longitudinal direction of the product. The shaped product exhibited excellent physical properties including a large tensile

strength of 581 MPa and a small thermal shrinkability of 0.3 %.

(Example 4)

A polyvinylidene fluoride resin of η inh=1.0 ("KF#1000", made by Kureha Chemical Industry Co., Ltd) was spun at a resin temperature of 260 ℃ through a 50 mm-dia. extruder to obtain an unstretched filament. The unstretched filament was subjected to a first step-stretching at 5.6 times in a glycerin bath at 170 ℃ and then a second step-stretching at 1.15 times in a glycerin bath at 165 ℃, followed further by relaxation by 10 % in a glycerin bath at 160 ℃ to obtain a stretched filament. The stretched filament exhibited a tensile strength of 752 MPa and an elongation of 35 %. Then, similarly as in Example 1, the stretched filament was set in a mold for injection molding as shown in Fig.3, and an identical resin as the stretched filament was injected at 240 ℃ into the mold to form a tape-shaped product as shown in Fig.1. The stretched filament occupied 40 % of a sectional area perpendicular to the longitudinal direction of the product. The shaped product also exhibited excellent physical properties similarly as the shaped product of Example 3.

(Example 5)

The same 6/66 copolymer nylon as used in Example 3 was formed into a stretched filament of 200

μm in the same manner as in Example 3 except for changing the second stretching ratio to 1.4 times. The stretched filament exhibited a tensile strength of 761 MPa. Then, similarly as in Example 1, the stretched filament was set in a mold for injection molding, and an identical resin as in Example 4 was injected at 240 ℃ into the mold to form a tape-shaped product as shown in Fig 1. The stretched filament occupied 40 % of a sectional area perpendicular to the longitudinal direction of the shaped product. The shaped product also exhibited excellent physical properties.

While the products of both Examples 4 and 5 exhibited excellent physical properties, the tape-shaped product of Example 4 exhibited better physical property in spite of almost equal strengths of the stretched filaments in these Examples. This is attributable to a difference in adhesion between the resin of the stretched filament and the injected resin. Thus, a better adhesion between a stretched filament and an injected resin results in better development of the property of the stretched filament in the tape-shaped product.

(Example 6)

A polyester resin (IV=1.0) was spun at a resin temperature of 275 ℃ through a 50 mm-dia. extruder to obtain an unstretched filament. The unstretched filament was stretched at 5.5 times and then relaxed by

15 % to obtain a stretched filament. Then, similarly as in Example 1, the stretched filament was set in a mold for injection molding as shown in Fig.3, and an identical resin as in Example 1 was injected at 280 ℃ into the mold to form a tape-shaped product as shown in Fig.1. The stretched filament occupied 40 % of a sectional area perpendicular to the longitudinal direction of the product. The shaped product exhibited similarly excellent physical properties as the product of Example 3.

(Comparative Example 4)

Stretched filament-containing tape-shaped product was prepared by injection of a resin different from the stretched filament.

〈4-(1)〉

A core-containing unstretched tape was formed by co-extrusion of an identical polyester resin as used in Example 6 and a polyester elastomer of MFR=1.0. The tape was then subjected to stretching and relaxation heat treatment in a similar manner as in Example 6 to obtain a core-containing stretched tape-shaped product (width=0.65 mm, thickness=0.24 mm, core diameter=0.2mm). As is understood from the physical properties shown in Table 1, the tape-shaped product exhibited a sufficient strength but failed to exhibit a size stability due to a large thermal shrinkability.

〈4-(2)〉

A tape-shaped product was tried to be formed in the same manner as in Example 1 except for using a stretched filament of polyvinylidene fluoride resin obtained in the same manner as in Example 4 and a polyester elastomer of MFR=10 identical to the one used in Example 1, but the stretched filament of polyvinylidene fluoride resin was melted at the time of injection molding.

TABLE 1

Example	Shaping method*	Stretched filament		Tape portion		Shaped product	
		Material**	Strength [MPa]	core	Material**	Strength [Mpa]	Shink [%]
1	SF-inserted injection	PEE MFR10	470		PEE MFR10	338	0.3
Comp.1-(1)	injection				PEE MFR10	61	0.1
Comp.1-(2)	USF-inserted injection	PEE MFR10			PEE MFR10	65	0.1
Comp.2-(1)	tape extrusion				PEE MFR10	70	0.1
Comp.2-(2)	tape extrusion-stretching				PEE MFR10	235	2.5
Comp.2-(3)	do.				PEE MFR10	198	0.3
Comp.2-(4)	do.				PEE MFR10	293	3.3
2	SF-inserted injection	core: PEE MFR10 sheath: PEE MFR17	437		PEE MFR10	320	0.3
Comp.3-(1)	core/tape extrusion			yes	core: PEE MFR10 sheath: PEE MFR 17	71	0.1
Comp.3-(2)	core/tape extrusion-stretching			yes	do.	198	2.3
Comp.3-(3)	do.			yes	do.	179	0.3
Comp.3-(4)	do.			yes	do.	250	3.1
3	SF-inserted injection	6/66 copolymer nylon	815		6/66 copolymer nylon	581	0.3
4	do.	PVDF	752		PVDF	522	0.3
5	do.	6/66 copolymer nylon	761		PVDF	419	0.3
6	do.	polyester	653		PEE MFR10	455	0.3
Comp.4-(1)	core/tape extrusion-stretching			yes	core: polyester sheath: PEE MFR10	365	3
Comp.4-(2)	SF-inserted injection	PVDF	752		PEE MFR10	PVDF melted	

* Abbriviation used: SF= stretched filament, USF=unstretched filament

**Abbreviation used: PEE=polyester elastomer, MFR= melt flow rate, PVDF= polyvinylided fluoride

Next, examples of production of ball chain belts are described.

(Example 7)

As shown in Fig.7, balls were set at equal intervals in a mold, the stretched filament prepared in Example 1 was disposed at such positions as to be contained along two edges parallel to the longitudinal direction of the resultant shaped product, and an identical resin (polyester elastomer of MFR=1.0) as the stretched filament was injected into the mold to obtain a ball chain belt as shown in Fig. 2 having a width of 2.24 mm, a thickness of 0.24 mm, a hole diameter of 1.63 mm and a hole-hole pitch of 1.73 mm. The stretched filament occupied a portion of sectional area perpendicular to the longitudinal direction at ratios of 5 % at a ball-retainer portion (spacer portion) and 43 % at a hole diameter position. As the physical properties thereof are shown in Table 2, the ball chain belt exhibited a high tensile strength and also a high strength at the ball-retaining position, and further a good size stability due to a small thermal shrinkability. The stretched filament exhibited a good adhesiveness without peeling.

(Comparative Example 5)

A ball chain belt (width=2.24mm, thickness=0.24 mm, hole diameter=1.63 mm, hole-hole pitch=1.73 mm)

as shown in Fig. 8 (wherein a dashed line 7 represents a ball-inset state) was obtained by injection molding in the same manner as in Example 7 except for omitting the stretched filament.

(Example 8)

A tape-shaped product having a width of 2.24 mm and a thickness of 0.24 mm prepared in a similar manner as in Example 1 was perforated to form holes having a diameter of 1.63 mm at a hole-hole pitch of 1.73 mm. Then, the perforated tape-shaped product was set in a mold, balls for molding were inset in the holes thereof, and insert molding was performed by injecting a polyester elastomer of MFR=10 to obtain a ball chain belt as shown in Fig.2.

(Comparative Example 6)

Tape shaped products of different stretching ratios were perforated and subjected to insert molding in similar manners as in Example 8 to produce ball chain belts.

〈6-(1)〉

An identical resin (polyester elastomer of MFR=10) as used in Example 7 was extruded through a 50 mm-dia. extruder to form a tape product (width=2.24 mm, thickness=0.24mm) as shown in Fig.4, which was then perforated to form holes having a diameter of 1.63 mm at a hole-hole pitch of 1.73 mm as shown in Fig.6. Then, the perforated tape-shaped product was set in a

mold, balls for molding were inset in the holes, and insert molding was performed to obtain a ball chain belt as shown in Fig.8.

〈6-(2)〉

An identical resin as used in Example 7 was extruded into a tape-shaped product in the same manner as in the above 6-(1), which was then stretched at 5.8 times in a hot air oven at 150 ℃ and then relaxed by 10 % in a hot air oven at 180 ℃ to obtain a stretched tape. The tape was used for perforation and insert molding in the same manner as in the above 6-(1) to obtain a ball chain belt as shown in Fig.8.

〈6-(3)〉

A ball chain belt was obtained in the same manner as in the above 6-(2) except for changing the stretching ratio to 6.9 times.

〈6-(4)〉

An identical resin as used in Example 7 was extruded into a tape-shaped product in the same manner as in the above 6-(1), which was then stretched at 6.25 times in a hot air oven at 180 ℃ and then relaxed by 30 % in a hot air oven at 220 ℃ to obtain a stretched tape. The tape was used for perforation and insert molding in the same manner as in the above 6-(1) to obtain a ball chain belt as shown in Fig.8.

In the above 6-(1) to 6-(4), there occurred molding failures, such as insufficient filling of resin at the

spacer portions and "fins" caused by entering of resin into holes.

(Example 9)

Insert molding was performed in the same manner as in Example 7 except for using the core/sheath composite stretched filament obtained in Example 7 to prepare a ball chain belt as shown in Fig. 2.

(Comparative Example 7)

Core-containing composite tapes were prepared by co-extruding a polyester elastomer of MFR=10 as a core resin together with a polyester elastomer of MFR=17, and used for production of ball chain belts as shown in Fig.9, wherein a dashed line 7 represents a ball-inset state.

〈7-(1)〉

A composite tape containing core was prepared by co-extruding a polyester elastomer of MFR=10 as a core resin together with a polyester elastomer of MFR=17. The tape was subjected to perforation and insert molding in the same manner as in Example 6 to obtain a ball chain belt as shown in Fig.9.

〈7-(2)〉

A core-containing composite tape was prepared by co-extruding a polyester elastomer of MFR=10 as a core resin together with a polyester elastomer of MFR=17 and there stretched at 5.8 times in a hot air oven at 150 ℃, followed by relaxation by 10 % in a hot air oven

at 180 ℃ to obtain a stretched tape. The tape was subjected to perforation and then insert molding in the same manner as in Comparative Example 6 to obtain a ball chain belt as shown in Fig.9.

〈7-(3)〉

A ball chain belt was obtained in the same manner as in the above 7-(2) except for changing the stretching ratio to 6.7 times.

〈7-(4)〉

A core-containing composite tape was prepared by co-extruding a polyester elastomer of MFR=10 as a core resin together with a polyester elastomer of MFR=17 and then stretched at 6.25 times in a hot air oven at 180 ℃, followed by relaxation by 30 % in a hot air oven at 220 ℃ to obtain a stretched tape. The tape was subjected to perforation and then insert molding in the same manner as in Comparative Example 6 to obtain a ball chain belt as shown in Fig.9.

In any case of the above 7-(1) to 7-(4), many defective products occurred due to difficulty of the molding, and the products obtained apparently normally were far from practical use due to small tensile strength and small strength at the retaining portions.

(Example 10)

The nylon stretched filament prepared in Example 3 was set in a mold as shown in Fig.7, and an identical resin as the stretched filament was injected into the

mold to obtain a ball chain belt (width=2.24 mm, thickness=0.24 mm, hole diameter=1.63 mm, hole-hole pitch=1.73 mm) as shown in Fig.2 in a similar manner as in Example 7.

(Example 11)

The polyvinylidene fluoride resin stretched filament prepared in Example 4 was set in a mold as shown in Fig.7, and an identical resin as the stretched filament was injected into the mold to obtain a ball chain belt (width=2.24 mm, thickness=0.24 mm, hole diameter=1.63 mm, hole-hole pitch=1.73 mm) as shown in Fig.2 in a similar manner as in Example 7.

(Example 12)

The nylon stretched filament prepared in Example 5 was set in a mold as shown in Fig.7, and an identical resin as the stretched filament was injected into the mold to obtain a ball chain belt (width=2.24 mm, thickness=0.24 mm, hole diameter=1.63 mm, hole-hole pitch=1.73 mm) as shown in Fig.2 in a similar manner as in Example 7. The stretched filament occupied a portion of sectional area perpendicular to the longitudinal direction at ratios of 5 % at a ball-retainer portion (spacer portion) and 43 % at a hole diameter position.

The products of Examples 11 and 12 both exhibited excellent results. The reason why the product of Example 11 exhibited better property is that

the adhesion between the stretched filament and the injected resin was better in Example 11 similarly as in the case of Examples 4 and 5.

(Comparative Example 8)

The polyvinylidene fluoride resin stretched filament prepared in Example 4 was set in a mold as shown in Fig.7, and a polyester elastomer of MFR=10 was injected into the mold for insert molding to produce a bal chain belt (width=2.24 mm, thickness= 0.024 mm, hold diameter=1.63 mm, hole-hole pitch=1.73 mm) as shown in Fig.2, in a similar manner as in Example 7, whereas the polyvinylidene fluoride resin was melted at the time of the insert molding.

(Example 13)

The polyester stretched filament prepared in Example 6 was set in a mold as shown in Fig.7, and a polyester elastomer of MFR=10 was injected into the mold to obtain a ball chain belt (width=2.24mm, thickness=0.24 mm, hole diameter=1.63 mm, hole-hole pitch=1.73 mm) as shown in Fig.2 in a similar manner as in Example 7.

The ball chain belts prepared in the above Examples 7-13 all exhibited sufficiently large tensile strength and strength at the retaining portion, thus showing excellent performances as a ball chain belt.

(Comparative Example 9)

Glass fiber (multi-filaments in a form of bundle of

120 filaments of each 9.4 μm in diameter) wound about a bobbin was supplied to a die and the polyester elastomer used in Example 7 was heated through an extruder and supplied to the die to be extruded so as to cover the glass fiber, thereby obtaining a core-containing composite tape-shaped product as shown in Fig.5. Then, the tape-shaped product was subjected to perforation and insert molding in a similar manner as in Comparative Example 6 to obtain a ball chain belt as shown in Fig.9, wherein the adhesion between the glass fiber and the polyester elastomer was insufficient to cause peeling of the glass fiber and cutting of filaments.

(Comparative Example 10)

A ball chain belt as shown in Fig.9 was prepared in the same manner as in Comparative Example 9 except for using carbon fiber (multifilaments in a form of bundle of 80 filaments of each 10 μm in diameter). In the belt, the adhesion between the carbon fiber and the polyester elastomer was insufficient to cause peeling of the carbon fiber and cutting of filaments.

TABLE2

Example	Shaping method*	Stretched filament		Ball retainer						Molding defects***
		Material**	Strength [MPa]	Extruded tape material**	Perforation	Injection molded material**	Tensile strength [MPa]	Retaining strength [MPa]	Thermal shrink [%]	
7	SF-inserted injection	PEE MFR10	470				213	73	0.3	A
Comp.5	injection					PEE MFR10	61	53	0.3	A
8	Method 1	PEE MFR10	470		yes	PEE MFR10	207	38	0.3	B
Comp.6-(1)	Method 2			PEE MFR10	yes	PEE MFR10	70	37	0.1	C
Comp.6-(2)	Method 3			PEE MFR10	yes	PEE MFR10	113	35	3.1	C
Comp.6-(3)	Method 3			PEE MFR10	yes	PEE MFR10	195	35	3.8	C
Comp.6-(4)	Method 3			PEE MFR10	yes	PEE MFR10	98	37	0.3	C
9	SF-inserted injection	core: PEE MFR10 sheath: PEE MFR17	437			PEE MFR10	208	110	0.3	A
Comp.7-(1)	Method 4			core: PEE MFR10 sheath: PEE MFR17	yes	PEE MFR10	68	35	0.2	C
Comp.7-(2)	Method 5			do.	yes	PEE MFR10	100	35	2.8	C
Comp.7-(3)	Method 5			do.	yes	PEE MFR10	165	34	3.3	C
Comp.7-(4)	Method 5			do.	yes	PEE MFR10	89	38	0.3	C
10	SF-inserted injection	6/66 co-Ny	815			6/66 co-Ny	464	140	0.2	A
11	SF-inserted injection	PVDF	752			PVDF	383	131	0.3	A
12	SF-inserted injection	6/66 co-Ny	761			PVDF	311	86	0.3	A
13	SF-inserted injection	polyester	653			PEE MFR10	329	130	0.3	A
Comp.8		PVDF	752			PEE MFR10	melted			
Comp.9	Method 4			core: glass fiber sheath: PEE	yes	PEE MFR10	melted & cut			
Comp.10	Method 4			core: carbon fiber sheath: PEE	yes	PEE MFR10	melted & cut			

*: SF=stretched filament; Method 1=SF-inserted injection→perforation→injection molding of spacer portion.
Method 2= tape extrusion→perforation→injection molding of spacer portion
Method 3= tape extrusion→stretching→perforation→injection molding of spacer portion
Method 4= extrusion of core-containing tape→perforation→injection molding of spacer portion
Method 5= extrusion of core-containing tape→stretching→perforation→injection molding of spacer portion
**: PEE= polyester elastomer, PVDF= polyvinylidene flouride, co-Ny=copolymer nylon.
***: molding defects (insufficient filling, fins) A=none, B=few, C=many

(Example 14)

As shown in Fig.11, rollers were set at equal intervals in a mold, and the stretched filament prepared in Example 1 was disposed at such positions as to be contained along two edges parallel to the longitudinal direction of the resultant shaped product, and an identical resin (polyester elastomer of MFR=1.0) as the stretched filament was injected into the mold to obtain a roller-type ball chain belt as shown in Fig. 12(a), (b) and (c) having a width of 2.24 mm, a thickness of 0.24 mm, a hole in a width direction of 1.63 mm and a hole-hole pitch of 1.73 mm. The stretched filament occupied a portion of sectional area perpendicular to the longitudinal direction at ratios of 5 % at a roller-retainer portion (spacer portion) and 43 % at a hole diameter position. The roller-type ball chain belt exhibited a high tensile strength and also a high strength at the ball-retaining position, and further a good size stability due to a small thermal shrinkability. The stretched filament exhibited a good adhesiveness without peeling.

(Example 15)

A ball chain was prepared by insetting balls in a ball chain belt obtained in the same manner as in Example 7. The ball chain was used to prepare a linear motion guide device as shown in Fig.13 including

a tracking rail 12, a moving block body 13 and the ball chain 14.

(Example 16)

A roller-type ball chain was prepared by insetting rollers in a ball chain belt obtained in the same manner as in Example 14. The ball chain was used to prepare a linear motion guide device 15 as shown in Fig.14 including a tracking rail 16, a moving block body 17 and the roller-type ball chain 18.

(Example 17)

A ball chain was prepared by insetting balls in a ball chain belt obtained in the same manner as in Example 7. The ball chain was used to prepare a ball screw 19 as shown in Fig.15 including a screw shaft 20, a nut member 21, a return pipe 22 and the ball chain 23.

It became clear that the linear motion guide devices prepared in Examples 14 and 15 and the balk screw prepared in Example 17 all withstood a long period of use, whereby it was proved that the ball chain belt and ball chain according to the present invention could be excellent members of such linear motion guide device and ball screw device.

[INDUSTRIAL APPLICABILITY]

According to the present invention of effecting injection molding after setting a stretched fibrous

member in a mold, it is possible to obtain a tape-shaped product having a large strength not attainable by a conventional extrusion product or a mere injection-molded product.

Further, a ball chain belt having a large strength obtained by subjecting such a tape-shaped product to perforation and injection molding of portions for retaining rolling members (such as balls or rollers) or by injection molding after setting a stretched fibrous member and balls for molding, is allowed to provide a product which exhibits a large strength not realizable by a ball chain belt formed by (co-)extrusion. Further, the stretched fibrous member disposed along both edges of the shaped product not only contributes to the strength but also reinforces the weld and remarkably reduces the molding defects.

By insetting prescribed balls (or rollers) in the ball chain belt thus-obtained of the present invention, a ball chain is obtained. The ball chain can exhibit excellent performances when incorporated in a linear motion guide device equipped with an endless circulation path, or a ball screw, etc.